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FMEA Approach of Lean Sig Sigma Implementation: Estimating the Value of COPQ

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Abstract

Lean and Six Sigma are a comprehensive concept in business systems. The strength of this concept is that it is able to provide tangible results for the company, so it requires implementation and measurable evaluation steps. The implementation step of Lean Sig Sigma must use two approaches, is a Lean approach to eliminate waste processes and reduce variations in products. This article discusses the changes resulting from the implementation of Lean Sig Sigma because there are differences in the cost of quality between the conditions before and after the implementation. Cost of Poor Quality (COPQ) is the cost due to defects in processes, products, and services. COPQ is defined as the costs that must be incurred to resolve failures and damage in the process. The measurement method used to estimate the value of CPOQ requires initial measurements. The constraint faced in this estimation was that there was no measure available at the start of the project. To overcome these limitations, we use a weighted risk approach based on potential failures to calculate the costs of the ongoing process. Furthermore, the paper also presents the steps in Lean Sig Sigma. In addition, the evaluation mechanism uses Lean Sig Sigma with the FMEA approach to COPQ.

Keywords: Lean , Sig Sigma, COPQ, FMEA

1. INTRODUCTION

Lean Six Sigma is a comprehensive concept in business systems. The lean concept comes from the Toyota management system concept which was developed and expanded, while the Six Sigma concept comes from the Motorola management system concept. The strength of the two concepts is synergized into Lean Six Sigma (Antony et al., 2017; Aboelmaged, 2010).

In order for Lean Six Sigma to be able to provide tangible results for the company, it requires implementation steps and measurable evaluation. The implementation steps for Lean Six Sigma must use two approaches. A lean approach to eliminating processes from waste and Six Sigma to reduce variation in products (Hill et al., 2017; Petrusch & Vaccaro, 2019; Harry & Scroeder, 2000).

One of the changes resulting from the implementation of Lean Six Sigma, there is a difference in the cost of quality which explains the conditions before and after the implementation. Cost of Poor Quality (COPQ) is the cost resulting from 'defects' on a process, product, or service. COPQ is also defined as the costs that must be incurred to deal with failure and damage in the process. Many methods are used to estimate the value of CPOQ because all of them require initial measurements (Prashar, 2014).

The constraint faced in estimating COPQ was that no measure was available at the start of the project. To overcome these limitations, we need to present a weighted risk approach from potential failures to calculate the cost of processes that are running in a company.

2. LITERATURE REVIEW

2.1. Theory of Lean

Lean as a business philosophy that is based on minimizing the use of various resources (including time) in various company activities. Lean focuses on identifying and eliminating non-value added activities in the design, production, or operation and supply chain management that are directly related to customers. Lean creates a self-sustaining culture by emphasizing the 5-S concept. This system will generate motivation for workers to always work effectively and efficiently. Lean thinking distills the lean approach into 5 main perspectives (Čiarnienė & Vienažindienė, 2012; Womack & Jones, 2005).

First, value is needed to identify product value from a customer perspective, where customers want products with superior quality, competitive prices, and on-time delivery. Second, the value stream as a process mapping which includes all the steps needed to design an order, produce goods or products and look for non-added value activities. Third, it is necessary to create a value flow, because various activities that provide added value are arranged into a continuous flow and eliminate non-added value activities. Fourth, organizing a pulled system so that materials, information, and products flow smoothly and efficiently along the value stream. Fifth, the perfection stage is aimed at continuous improvement, so that the waste that occurs can be completely eliminated from the existing process (Holden, 2010).

2.2. Sig Sigma Approach

Six Sigma is a quality management system that is always oriented to customer satisfaction with a sigma quality level target measurement. Sigma (s) is a symbol that describes the distribution or distribution of the process mean value (standard deviation). This sigma value is used as a measuring tool to show the performance of a process. The Sig Sigma process with a normal distribution allows the average value to shift 1.5 sigmas from the quality target specification (T) value desired by the customer (Ganguly, 2012; Dutta & Jaipuria, 2020; Schroeder, 2008).

There are five basic steps or steps in implementing the Sig Sigma strategy, i.e Define-Measure-Analyze-Improve-Control (DMAIC). From the stages, it is a recurring part and forms a cycle of quality improvement for Sig Sigma. The DMAIC cycle is presented in Figure 1.

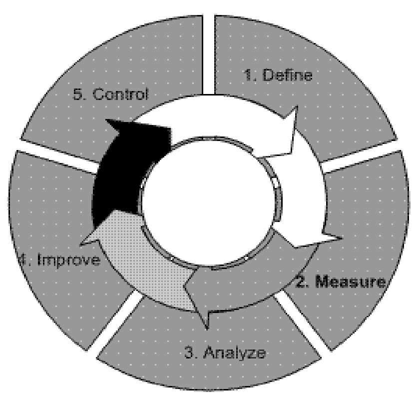

Figure 1: DMAIC cycle
Source: Pande et al. (2000)

Six Sigma as a quality program is also a tool for problem-solving. Sig Sigma emphasizes methodically and systematically which will result in a breakthrough in quality improvement. This systematic methodology is generic, so it can be applied in both the manufacturing and service industries. Sig Sigma is also said to be a process-focused method and defect prevention. Prevention of defects is done by reducing the variation in each process by using statistical techniques that are generally known (Snee, 2004; Montgomery & Woodall, 2008).

The benefits of implementing Sig Sigma are different for each company concerned, depending on the business they are running. Typically, this approach will lead to improvements in cost reduction, productivity improvements, market share growth, customer retention, reduced cycle times, defect reduction, and product or service development. Judging from the tools used, Sig Sigma is quite broad. Figure 2 shows the commonly used methods of Sig Sigma (Hammer & Goding, 2001; Raisinghani et al., 2005; Ghaleb et al., 2004).

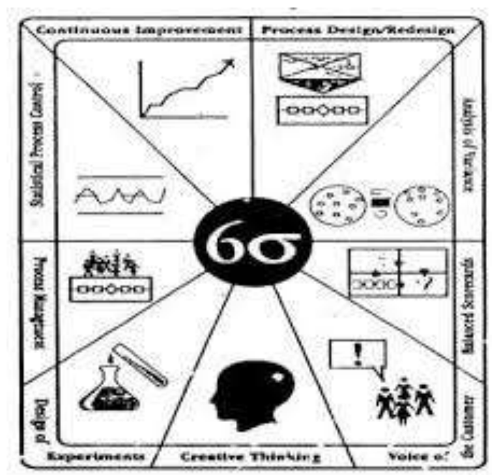

Figure 2: Six Sigma with its tools
Source: Brue (2002)

Efforts to improve towards the Sig Sigma target can be done with the DMAIC methodology with several stages. Formally define process improvement goals consistent with customer demands or needs and company strategy. Measure current process performance so that it can be compared with the target set. Perform process mapping and collect data related to key performance indicators. Analyze the causal relationship of various studied factors to determine the dominant factors that need to be controlled. Optimizing the process using analysis such as Design of Experiment (DOE), to determine and control the optimum process conditions. Controlling the process continues to improve process capabilities towards the Sig Sigma target (Rahman et al., 2017; Kusnadi & Yudoko, 2016).

Table 1: Sigma level values

Specification limits	Percent	Defective (ppm)
$\pm 1\sigma$	30.23	697.700
$\pm 2\sigma$	69.13	308.700
$\pm 3\sigma$	93.32	66.810
$\pm 4\sigma$	99.38	6.210
$\pm 5\sigma$	99.98	233
$\pm 6\sigma$	99.99	3.4

Source: Harry & Scroeder (2000)

In general, the successful implementation of the Sig Sigma concept is measured by the sigma value achieved. This value is an interpretation of the number of errors that occur per one million units. The higher the sigma value achieved, the better the industrial process performance is. Table 1 presents the Sig Sigma quality level, which is the quality level where the process with a 6s spread of the average process still meets the specified specification limit. At this quality level, there are only 3.4 defects resulting from 1000,000 defects (defects per million opportunities).

Table 2: The relevance of Sigma Level, DPMO and COPQ

Sigma level	DPMO (criteria)	% COPQ of sales value
1	697,700 (highly uncompetitive)	Can not be calculated
2	308,700 (Indonesian industry average)	Can not be calculated
3	66,810	25% - 40%
4	6,210 (USA industry average)	15% - 25%
5	233 (Japanese industrial average)	5% - 15%
6	3.4 (world class industry)	< 1%

Source: Gaspersz (2002)

Quality improvement as a result of implementing Lean Sig Sigma along with achieving the sigma level can be measured based on the percentage of COPQ to sales value (see Table 2).

2.3. Cost of Poor Quality (COPQ)

COPQ is the cost due to defects in processes, products, and services. COPQ is the initial financial analysis that resulted in the implementation of the Lean Sig Sigma project. COPQ is also a cost that must be incurred to resolve failures and damage in the process. Costs incurred are influenced by 4 factors such as the probability of each failure occurring, how serious the condition will be if a failure occurs, provisions for finding the cause of errors, and the cost of handling one failure (Troy & Schein, 1995).

Many methods are used to estimate CPOQ values and all require initial measurement. The constraint faced in estimating COPQ was that no measure was available at the start of the project. However, an approach can be used to calculate the cost of an ongoing process using the weighted risk of potential failures. One of them is by using FMEA (Moen, 1998; Krishnan, 2006; Giakatis et al., 2001; Ghobadian et al., 1994).

3. MEASUREMENTS

3.1. Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a method that functions to show problems that may arise in a system, because it can cause the system to be unable to produce the desired output and then determine countermeasures (before the problem occurs). Thus, problems in the production process that affect product quality can be reduced, so they will be eliminated by themselves. Basically, the FMEA program wants to know 3 things which include the potential causes of failure of the product during its life cycle, the effect of these failures, and the level of criticality of the effect of failure on product function (Ben-Daya, 2009; Wang et al., 2017).

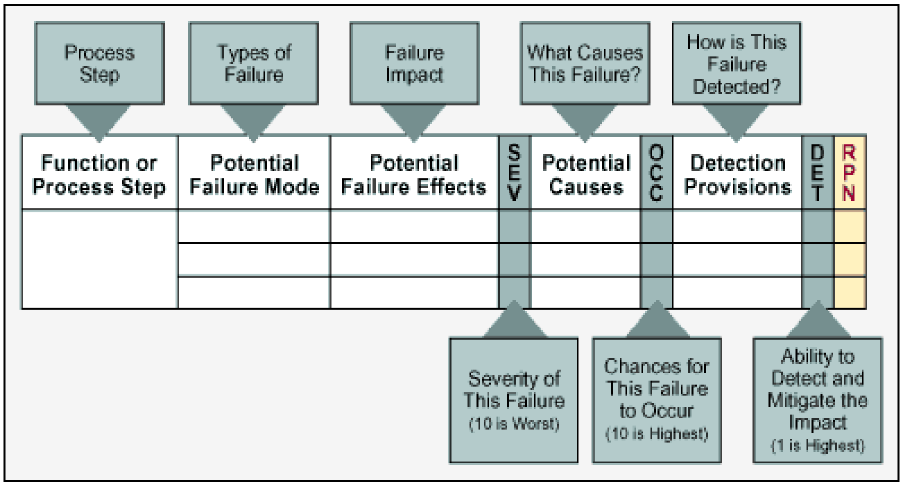

Figure 3: FMEA worksheet
Source: Schneider (1996)

Figure 3 shows the FMEA worksheet which consists of an estimate of the potential failure that may arise in the system, the estimated effect of the problem on the product (effect), determining the cause of each failure, and determining the priority order of troubleshooting based on the frequency and degree of failure (George, 2002).

3.2. Lean Sig Sigma Implementation and Evaluation Design

FMEA is carried out in the measure (analyze) phase and control on the project DMAIC, to provide the basis for estimating COPQ. The use of FMEA in estimating COPQ is carried out in the following steps:

Step 1: Identify potential causes of failure using the input-output diagram and transfer it to the FMEA worksheet. Use a cause-and-effect matrix, to ensure that all types of failure are included in the COPQ analysis. Enter only the controlled input (factor), this is important because the costs for uncontrolled factors cannot be calculated with certainty.

Step 2: After inputting input, review with the team to ensure all potential failures have been identified. Include every possible failure. If there is a risk of failure, the team must identify it and include the potential cost of failure in the COPQ calculation.

Step 3: Calculate risk priorities for all potential failures using FMEA. Calculate the value of risk priority number (RPN) by considering the value of severity, occurrence, and detection.

Risk Priority Number = Severity x Occurrence x Detection

Where: Severity is the ranking of the severity of the failure mode effect for customers, Occurrence is the ranking of the causes of the failure mode during product use, and detection is the ranking of the current control system capable of detecting the occurrence of failure mode and preventing it from reaching the customer.

Step 4: Use team input and all available estimation tools. Then, calculate the Average Cost to Resolve (ACR) for each potential cause of failure. ACR is calculated as the product of the estimated time to solve the problem (Estimated Effort Hours to Resolve = EHR) and the average.

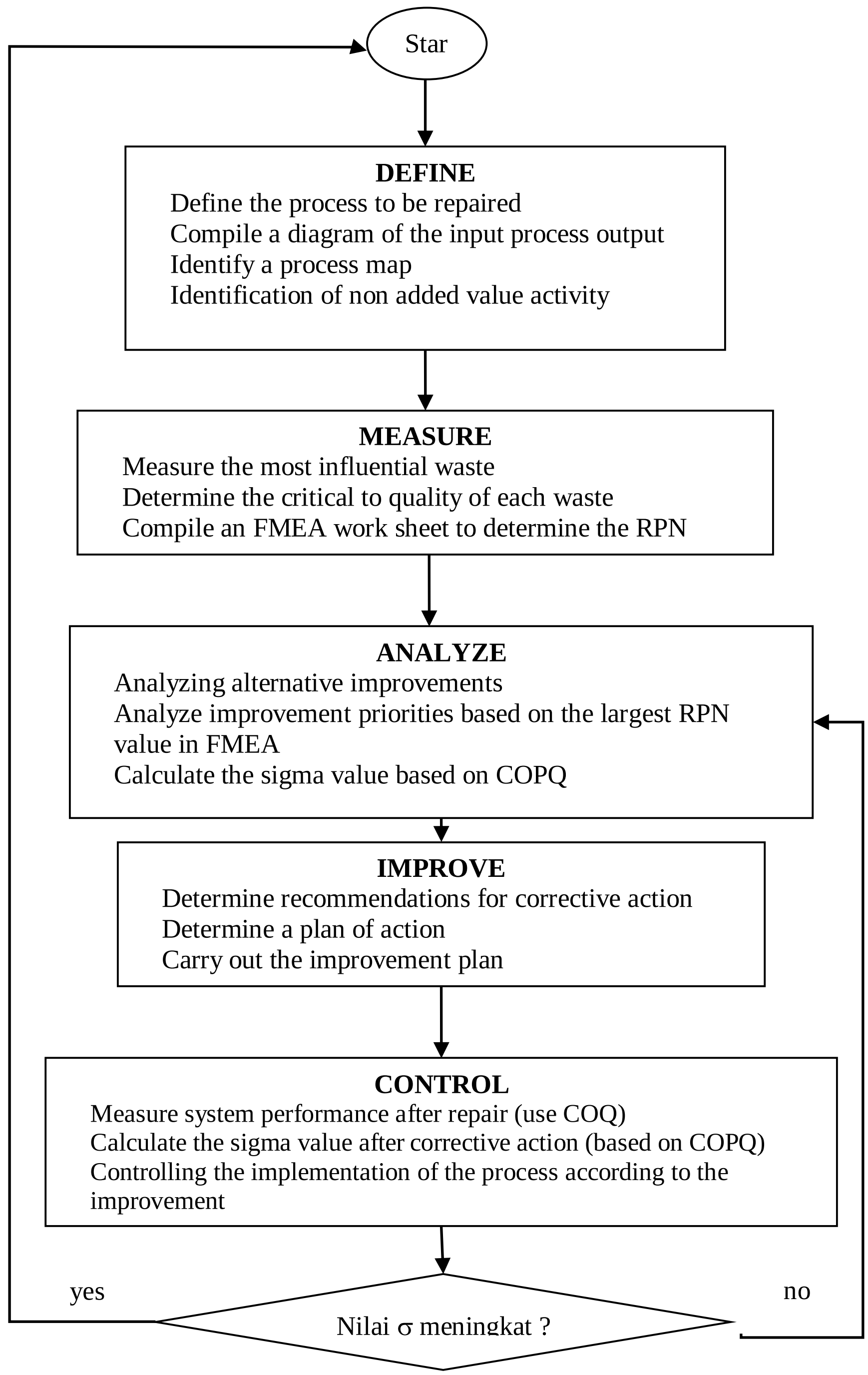

Figure 4: Lean Sig Sigma procedure flow chart

The hourly completion cost (ACH) is estimated here using a 90% -95% confidence level.

$$ACRi = EHRi \times ACHi$$

Where: ACRi is the average cost to solve problem i, EHRi is the time needed to solve the problem i, ACHi is the average cost per hour to solve problem i, and i is 1 to n (n total number of failures).

Step 5: Calculate the average cost required to solve a random problem, using the weighted average of the time to solve the problem. Weighting uses the risk priority for each failure.

Weighted Average Cost to Resolve (WACR) = [Sum of (RPNi x ACRi) / Sum of (RPNi)]

Step 6: Calculate the COPQ of the project by multiplying the WACR by the case reduction target during the project.

COPQ = WACR x Reduction in Events Due to the Project

4. RESULT AND DISCUSSIONS

The Sig Sigma team at Bank "X" was tasked with reducing the number of failed transactions resulting from 400 cases to 300 cases per month. No data was collected in the past either on cases or their measurements. However, team members can find out what caused the failure. In the absence of measurements, the team attempted to estimate the COPQ. The financial estimate related to the calculation of troubleshooting time is an important parameter to validate the results of this improvement project. As a solution, the team will use a risk prioritization approach with FMEA to estimate the COPQ. There are 2 steps taken by the team through define and measure.

This project is carried out to improve the service process at a bank, aiming to reduce customer queuing time by making improvements to service speed and factors that can reduce queues. Inputs from the service process are employee skills, transaction procedure computer systems, and transaction forms. The resulting output is in the form of customer service time (5 ± 2 minutes), the transaction value per month is Rp. 250 million ± 10 million, and customer satisfaction on a scale of 8-10. The customer service process is as shown in Figure 5. Based on the value stream mapping, it is known that 55% of all activities are value-added activity, 20% are necessary but non-added activity and 25% are non-added activity. The existence of non-added activities results in ineffective bank performance and efficiency.

From the process map, the biggest waste identified in this activity is waiting for the result of rework. From the input-output process, the causes of waste are identified. Furthermore, written in the FMEA worksheet. The steps are as follows:

Step 1: The team uses the input-output diagram to identify all potential causes of failure. Four causes were identified and imported into the FMEA tool. The four causes are employee skills, computer systems, transaction procedures, and transaction forms

Step 2: Next, the team meets to brainstorm and identify other causes. From this brainstorming, one main cause would be identified (damaged ATM), so that the cause was identified with a total of 5 cases.

Step 3: Calculating the RNP for the five causes of failure using FMEA tools.

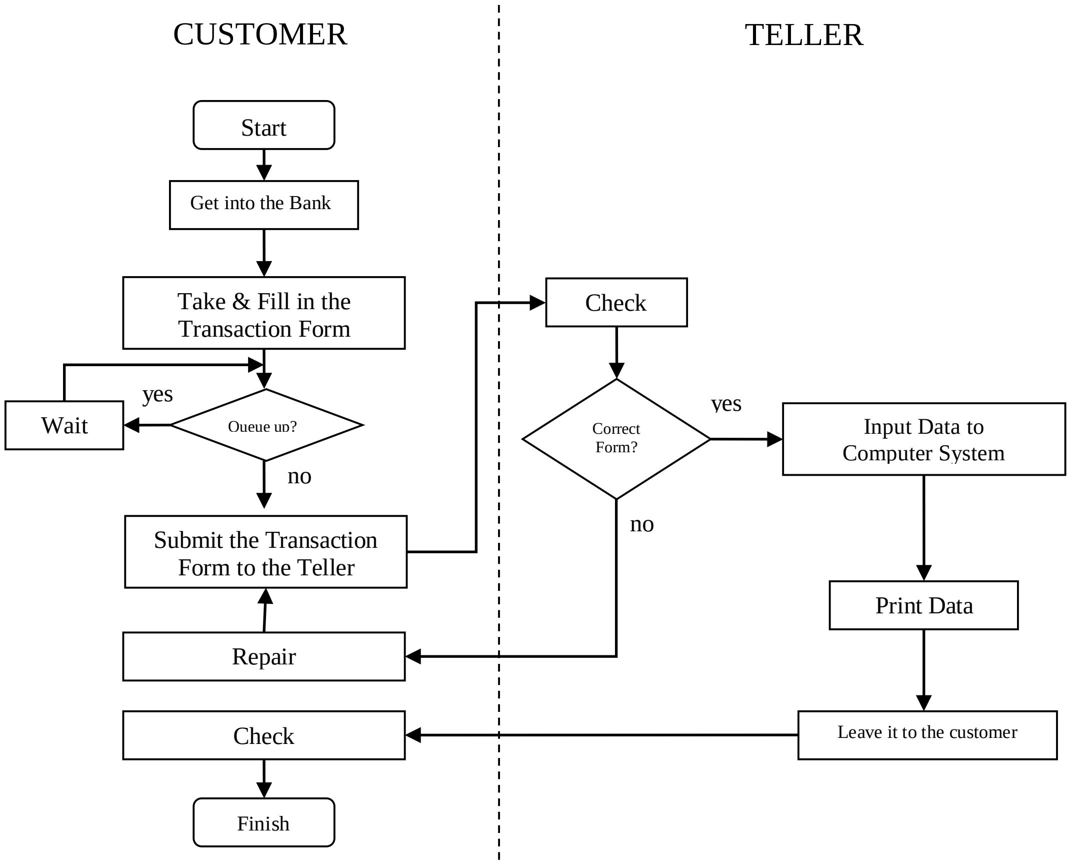

Figure 5: Process flow

Step 4: Then, the team reviews each cause of failure and calculates the average cost of dealing with the failure caused by that factor. Here, it takes an estimate of the problem-solving time and the average cost per unit of time.

Table 3: RPN calculation

Potential causes	Severity	Occurence	Detection	RPN
Employee skills	7	5	0.2	7.0
Computer system	5	5	0.5	12.5
Transaction procedure	6	9	0.8	43.2
Transaction form	8	9	0.8	57.6
ATM has broken	4	5	0.3	6.0

Source: Own tabulations

Step 5: Use the estimated average cost per case to calculate the weighted average weight estimate for solving the problem (WACR).

Weighted Average Cost to Resolve (WACR) = (RPN x ACR) / RPN

= Rp.19,990,000 /126.3 = Rp. 158,274

Table 4: COPQ calculation

Potential causes	RPN	Effort Hours to Resolve (hours)	Average Cost Per Hour (Rp.000)	Average Cost to Resolve (Rp.000)	RPN x ACR
Employee skills	7.0	1	50	50	350
Computer system	12.5	4	100	400	5,000
Transaction procedure	43.2	1	50	50	2,160
Transaction form	57.6	1	50	50	2,880
Weather	6.0	16	100	1,600	9,600
Total	126.3	23	350	2,150	19,990

Source: Own tabulations

Notes: Effort Hours to Resolve (EHR), Average Cost per Hour (ACH), Average Cost to Resolve (ACR).

Step 6: Finally, COPQ is estimated by multiplying the cost of resolving failures by the potential occurrence of failures per year.

COPQ (annualized)= [Sum of (RPNi x ACRi) / Sum of (RPNi)] x Annual Reduction in Events

The estimated occurrence of this failure is 400 cases per month, so that in 1 year as many as 4,800 cases per year.

COPQ in 1 year = Rp. 158,274 x 4,800 = Rp. 759,715,200

So, if there are 400 failures per month (4,800 per year), the COPQ that occurs is Rp. 759,715,200. When compared with the transaction value per year is Rp. 250 million x 12 = Rp. 3 billion, then this COPQ reaches 25.32%. Based on Table 2, this value indicates the sigma level 3.

To improve services, there are 4 alternative corrective actions that are considered by conducting training to improve employee skills, changing the computerized system, improving transaction procedures, and improving transaction forms. From the FMEA worksheet, it can be seen that the transaction form has the highest RPN value, so it is classified as an alternative improvement that has the highest priority to be implemented. The bank management targets this year to be able to reduce the occurrence of delays in service from 400 cases to 200 cases. Therefore, the COPQ value and the sigma value will be analyzed in this condition. From the calculation, the COPQ value is Rp. 379,857,482 or 12.66% of the annual sales value, so as to achieve the sigma value of 4.

Improvements are made in accordance with alternative improvements that have the highest RPN value, namely improvement of the transformation form.

If the implementation has been carried out, it is necessary to take control measures to ensure the implementation of improvements in accordance with the provisions. Apart from that, the COPQ value and the sigma value were also calculated to find out whether the method was able to improve the quality of the process. The calculation process uses the FMEA approach.

Several empirical studies conducted by Ridwan & Noche (2014), Sörqvist (1997), and Edgeman & Bigio (2004) have supported the findings in this article, that FMEA is a structured approach, so this calculation is relatively easy to do. Accuracy and ability to know the relationship (dependency) of each case and its severity, will result in COPQ estimates close to the actual value.

5. **CONCLUSIONS**

The combination of the Lean Thinking and Sig Sigma approaches will produce a quality process in a fast time and at low cost, because the two work together. Sig Sigma produces quality products, so it will spur lean speed to minimize rework time. On the other hand, lean speed has helped Sig Sigma in producing quality products because it is driven by the experimental process and the learning process quickly.

The successful implementation of Sig Sigma can be seen from the number of costs resulting from the production of poor quality products (COPQ). The lower the COPQ value, it shows that the process needs a relatively small cost of handling failure. This means that the process is able to produce good quality products and the achievement of the sigma level by higher processes.

If the Sig Sigma project team calculates the COPQ value at the measuring stage, then the FMEA approach will be very helpful because this approach objectively estimates COPQ which is constrained by the absence of past data and available measurement systems.

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